OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

RESTRICTED

DP/ID/SER.A/1052
23 August 1988
ORIGINAL: ENGLISH

17005-E

POLLUTION CONTROL RESEARCH INSTITUTE, HARDWAR

DP/IND/83/008

INDIA

Technical report: Air pollution control*

Prepared for the Government of India
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Michael Graber, expert in air quality

Backstopping officer: S. Maltezou, Chemical Industries Branch

United Nations Industrial Development Organization
Vienna

---

* This document has not been edited.

V.88 27857

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AC - Air Conditioner
AMV - Air Monitoring Van
AP - Air Pollution
AQ - Air Quality
ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers (Atlanta, GA, USA)
ASTM - American Society for testing and Materials (Philadelphia, PA, USA)
BHEL - Bharat Heavy Electrical Limited (Haridware, U.P., India)
CBPCWP - Central Board for the Prevention and Control of Water Pollution (New Delhi, India)
CFFP - Central Forging and Foundry Plant (BHEL, Haridware)
CO - Carbon Monoxide
EIA - Environmental Impact Assessment
HEEP - Heavy Electrical Equipment Plant (BHEL, Haridware)
NO - Nitrogen Monoxide
NOX - Nitrogen Oxides
O3 - Ozone
OCV - Organic Compound Vapors
PC - Personal Computer
PCRI - Pollution Control Research Institute (BHEL, Haridware)
PPDC - Process and Product Development Centre (Agra, U.P., India)
SO2 - Sulphur Dioxide
SPM - Suspended Particulate Matter
THC - Total HydroCarbons
UNAMAP - User's Network for Applied Modeling of Air Pollution
UNDP - United Nations Development Programme
UNEP - United Nations Environmental Programme
UNIDO - United Nations Industrial Development Organization
USEPA - United States Environmental Protection Agency
WHO - World Health Organization
WMO - World Meteorological Organization

2. ABSTRACT

The Pollution Control Research Institute (PCRI) of the Bharat Heavy Electrical Limited (BHEL), Haridwar, U.P., India, with the assisstance provided by the UNDP in New Delhi and the UNIDO in Vienna, has purchased instrumentation for air pollution monitoring and stack sampling measurements, and trained engineers to operate this equipment.

The present report is based on the findings following the first mission to India of M. Graber in March, 1987, under UNIDO Project # DP/IND/83/008.

The following subjects are addressed in this report:

- Background air quality monitoring around the Taj Mahal, Agra, using the PCRI air monitoring van during the Holli Feast (March,1987).

- Evaluation of AP Training Course suggested for the PCRI staff.

- Evaluation of AP equipment purchased and suggested for PCRI.

- AQ topics discussed and reviewed with the PCRI AP team in Haridware, including: Emission rates from iron cupolas, AQ mathematical modeling, AQ standards vs. emission standards, Environmental impact assessment, Site selection for the air monitoring van, and Air pollution measurements inside and around industrial plants.

A proposed outline for the continuation of Project #DP/IND/83/008 is presented.

3. ACKNOWLEDGEMENT

The author of this report would like to express his gratitude for the cooperation, help and hospitality extended to him by all those in India involved in the project, and in particular to Prof. S.P. Mahajan (Head of PCRI), to Mr. A.K. Gupta (Air Pollution Manager, PCRI) and to their staff, and to Mr. A.K. Gaur (Principal Director, PPDC).

The author is also indepted to Dr. M. Kamal Hussein (Senior Industrial Development Field Adviser, UNDP, New Delhi) and to Dr. Sonia P. Maltezou, Chemical Industries Branch, UNIDO, Vienna, for their guidance and help.

4. INTRODUCTION

The central issue of Mission DP/IND/83/008 in India in March 1987, namely, monitoring air pollution levels near the iron foundries and the Taj Mahal in Agra, is described in Sec. 5.

Sec. 6 (Comments on: "Austroplan" training program), Sec. 7 (Comments on: Quotation for a mobile van for source monitoring), and Sec. 8 (Performance evaluation of the UPK air monitoring van during the Agra Project) are included in this report at the request of Dr. Sonia Maltezou, UNIDO, Vienna.

Sec. 9 (Selected topics) contains various subjects that were discussed during the mission in India with the PCRI AP staff.

The appendices contain the detailed program executed during the field mission in India (App. 12.1), the list of AP support staff (App. 12.4) and AQ monitoring equipment (App. 12.5) at the disposal of PCRI, photographs taken during the Agra air monitoring project (App. 12.9). Other relevant information pertaining to the mission is included in the rest of the appendices.

5. AGRA AIR POLLUTION STUDY (PHASE 1 - BACKGROUND AIR POLLUTION LEVELS) - HOLLI, MARCH, 1987

5.1 The irreversible damage caused by air pollution to many famous stone and marble monuments in Europe and North America is by now widely known and well documented (Graedel & McGill, 1983). The list of examples of adversely affected marble monuments includes the Acropolis in Athens, Greece (Yocom, 1979), the City Hall in Schenectady, in New York, USA (Cheng & Castillo,1984), and marble tombstones in Philadelphia, in Pennsilvania, USA (Feddema & Meierding,1987).

Marble and limestone both are made almost entirely of calcite (calcium carbonate - $CaCO_3$), and the difference between them stems from the fact that in the marble the calcite has undergone crystallization. Acid rain, as well as SO_2 and NOX in the presence of water, reacts chemically with the calcite and transforms portion of it into gypsum (hydrated calcium sulphate - $CaSO_4.2H_2O$) and calcium nitrate ($CaNO_3$) (Cheng et al., 1987). The gypsum and calcium nitrates are soluble in water, and thus, those portions of the marble transformed into gypsum or $CaNO_3$ and exposed to precipitation are gradually washed away (Gauri & Holdren, 1981).

Further damage to marble monuments is caused by SO_2 by its corrosive action on the iron bars and pins which are used to attach marble blocks to the structural framework and to fasten adjacent blocks one to another (Kucera, 1976; Gauri & Holdren, 1981). Marble deterioratiopn is also caused by soot particles (Beloin & Haynie, 1975; Del Monte et al., 1981; Gauri & Holdren, 1981).

The mechanism of stone weathering and novel stone preservation techniques were discussed by Gauri (1978).

5.2 Recently, grave concern has been expressed regarding the fate of the Taj Mahal and other marble and stone monuments of national importance in Agra, India, because of the growing amounts of air pollutants (especially, of SO_2) emitted by industrial plants in the area. As the main SO_2 sources in the area were identified the many small iron foundries in Agra, as well as the huge new Indian Oil Corp. refinery (refining capacity of 6 million tons of crude per year) which is located near Mathura, about 40 km North-West of Agra. It was estimated that SO_2 emissions from the Mathura refinery amount to 25-30 tons/day (Gauri & Holdren, 1981).

In the survey conducted in 1981 by the Central Board for the Prevention and Control of Water Pollution - CBPCWP (the Federal Government of India, New Delhi) it was found that the iron foundry industry in the Agra area is the largest local emitter of SO_2, contributing about 60% of the SO_2 emissions in Agra (CBPCWP, 1981). In the CBPCWP report it is recommended to engage an expert team to improve cupola practices in the local iron foundries and reduce the amount of coke required by them for the iron smelting, from the current ratio of iron-to-coke of 2:1 to the ideal ratio of 8:1, thus significantly increasing the thermal efficiency of this industry, as well as greatly reducing its SO2 emissions.

To protect the Taj Mahal and the other stone monuments of national importance in the Agra area from future AP damage, the CBPCWP (1981) also recommended that any activities that contribute to the air pollution levels be kept to a minimum, both in the North-West and the North-East quadrants of the city of Agra.

5.3 Regarding AP damage to stone monuments in Agra, the following should be noted:

(1) Measurements of atmospheric SO2 concentrations performed in the Agra area in 1981 by the CBPCWP have shown that the SO2 levels at that time were relatively low (CBPCWP, 1981).

(2) Measurements of the Monsoon rain in India, and particularly in New Delhi, have shown that in India, due to the high atmospheric dust content, the Monsoon rain tends to have an alkaline, rather than an acid, pH (Subramanian & Saxena, 1980; Khemani et al., 1985).

(3) There is no reliable information regarding the sulphur content of the coke used by the iron foundry industry in the Agra area. It should be noted that the Indian coal is known to have usually a low sulphur content.

(4) It should be mentioned that with the assisstance of UNIDO and UNDP in Delhi, Dr.Ing. J. Marcinkowski, the Polish expert on iron foundries, has been invited to the PPDC in Agra to consult on the local foundry practices and to improve them.

(5) The coke supplied to the iron foundries in Agra is of a low quality (not hard coke but rather "Beehive Coke", with a high ash content and of low calorific value).

5.4 The AP team of the PCRI undertook upon itself to investigate, on behalf of the Agra Iron Foundries Association, the impact of this industry on the AQ in the Agra area, as well as to provide specific and reliable information regarding the following issues (see App. 12.8):

- the background levels of air pollutants in the area (namely, SO2, SPM, NOX, CO, O3) (Phase 1).

- the contriburtion of the iron foundry industry to the AP levels in the Agra area (Phase 2).

5.5 The complete shutdown of the iron foundries in Agra for the Holli Feast and the following week was utilized to obtain the background AP levels in the area (see App. 12.9 and App. 12.10). The results obtained in Agra by the PCRI Air Monitoring Van (AMV) are now being analyzed and will be reported later (see outline of the report, App. 12.11). Nevertheless, some preliminary findings can be reported here:

(1) The PCRI AMV, on the whole, operated satisfactorily, although there are some comments and suggestions for improvements (see Sec. 8).

(2) The background levels of all the pollutants measured during the Holli shutdown, except the SPM, were very low. In particular, the SO2 levels were low. It should be noted that the Mathura refinery was apparantly not closed down at the time of the Holli feast.

(3) Further AQ monitoring will be necessary to establish the impact of the foundries on the AQ in Agra. These measurements will have to be carried out when the foundries are operating.

(4) Other sources of SPM in the area seem to be contributing significantly to the Agra dust problem. These sources will not be addressed in the report pepared by PCRI to the Agra Iron Foundry Assosiation. Two of the most visible SPM sources in Agra seem to be: Traffic (mainly diesel vehicles such as trucks and Tempo cabs), and the large number of electric gasoline and diesel generators which are turned on whenever there are power failures in the area.

(5) Some of the older iron foundries are located in residential areas in the center of Agra. The newer foundries seem to be located in the industrial zone North and North-East to Agra, and further away from both the Taj Mahal and the residential areas in the center of Agra.

5.6 It is recommended to widen the scope of the investigation carried out by PCRI and include also:

(1) Determination of the range of the sulphur content of the coke supplied to the Agra iron foundries, as well as the sulphur content of the crude refined at the Mathura oil refinery. This information is vital, in conjunction with the survey of the Agra iron foundries carried out by the PPDC, to establish a reliable SO2 emmision inventory for the Agra area.

(2) Determination of the acidity of the rain in the Agra area.

(3) Quantitative determination wether, and if yes how much, the marble and stone of the Agra national monuments have eroded, and particularly, their content of gypsum and soot.

6. COMMENTS ON "AUSTROPLAN" TRAINING PROGRAM (AIR AND WATER POLLUTION PROPOSAL)

6.1 On the whole, a very good proposal. The sections of the proposal pertaining to third week (environmental hazards and safety in process plants) and to fourth week (environmental impact assessment - EIA) are especially important since the trainees do not seem to have any prior knowledge on these subjects.

6.2 Within the phase of "Plant Training" (p. 4), it is suggested that attention is paid to typical industries in India such as cupola iron foundries, brick kilns, cement plants, cane sugar mills, where all emissions into the air are uncontrolled. The training should cover non-standard methods of testings applicable to these types of industries.

6.3 It is suggested that the trainees should receive, as part of their laboratory training, some instructions on how to use a personnal computer for calculation of the results and analyses of these results.

7. COMMENTS ON: "QUOTATION FOR A MOBILE VAN FOR SOURCE MONITORING" - UPK (20.10.86)

7.1 Since the pollution concentrations in stack emissions are usually 3 orders of magnitude greater than the ambient concentrations, much less sensitive (and delicate) instruments can (and are) employed for stack emission analysis. There is one great advantage of using existing air quality (ambient) monitoring instruments (with an appropiate dilution system), as proposed by UPK, as this configuration allows a continuous reading of results over the whole period of sampling time (usually several hours). Since the configuration proposed by UPK is fairly new, it is suggested that UPK submits a list of clients who have received and successfully used this equipment.

7.2 It is suggested that the mobile van should posses a 4-weel drive to enhance its off-road performance. This requirement could prove to be very important for the present road system and climate in India.

7.3 All the instruments offered in the proposal for the stack sampling van (except for the SO_2 instrument) are identical to those installed in the Air Monitoring Van delivered by UPK to PCRI (see Sec. 8):

(1) The FID SO_2 monitor (Bendix 8303) installed in the Air Monitoring Van takes 1.0-1.5 hours to stabilize, before useful readings of SO_2 can be taken. This severe disadvantage might be rectified with the fluoroscence SO_2 monitor (UPK) offered for the stack sampling van in this proposal. Another advantage of the UPK SO_2 monitor is that it does not require Hydrogen for its operation.

(2) As seen also in our Agra AP study, the results of the photometric SPM monitor do not, usually, correlate well with results obtained with high volume samplers (which is the reference method). In any event, the photometer does not seem to be a good choice for monitoring dust emissions from stacks, especially because it is not sensitive to the larger sizes of particles which are abundant in the flue gases.

(3) It is suggested to add to the capability of the van the monitoring of the concentrations of CO_2 in the flue gas.

(4) On the other hand, it is suggested to delete the instrument for THC, which is not very useful for flue gas measurements. Also, without the THC instrument, and with the different type of SO_2 monitor, no Hydrogen gas will be needed in the van.

(5) It is extremely important to add to the van the capability to monitor in the stack the H_2O vapor content, the flue gas exit velocity and the flow rate.

(6) It should be noted that the state-of-the-art CO monitors are based on Gas Filter Correlation (GFC) and not NDIR.

7.4 It must be emphasized that for the climate in India a special heavy-duty air conditioner is required. The proper operation of the AC is of vital importance in India for performing the callibration procedures of the instruments.

7.5 The power output of the generator in the proposed stack sampling van is identical to the one supplied to PCRI in the Air Monitoring Van (i.e., 5.6 KVA). From our experience in the Agra AP project, many trips of the electrical systems occured, and this power may not be enough (perhaps because of the heavy load of the AC). Use of a different 10 KVA generator provided by PPDC rectified the problem. It is therefore suggested to provide a larger voltage generator.

7.6 For many of the industries common in India, the temperature of the exit gases is higher than 400 deg C. It is suggested that the probes supplied with the van withstand temperatures of at least 500 deg C.

7.7 Spare parts are an extremely difficult problem in India. The proposal should therefore include a generous supply of spare parts for all the instruments, including generator, pumps, AC, and the vehicle itself (see UNDP-Delhi instructions to foreigners importing their cars to India, on the subject of spare parts).

7.8 Presenting part of the proposal in German, rather than in English, causes a difficulty to the PCRI staff (see the part on the callibration system). Therefore all the material should be submitted in English.

7.9 The data handling and presentation system in the proposed stack sampling van is identical to that delivered to PCRI in the AMV:

(1) There is a distortion in the line of titles of the output data, which makes the data reading very tiresome.

(2) Much of the data includes to many significant numbers (i.e., temperature is given to the third significant number, although one is totally sufficient. The same applies to windspeed, radiation, pressure, relative humidity, CO and THC). This is unescessary and also confusing.

(3) It is suggested that UPK supplies with the data handling system also the source of the software so that PCRI staff can introduce changes and modifications in it as required by them.

8. EVALUATION OF THE PERFORMANCE OF THE UPK AIR MONITORING VAN DURING THE AGRA HOLLI PROJECT 18 - 23 MARCH, 1987)

On the whole, the performance of the UPK Air Monitoring Van (AMV) during the Agra Holli Project (18 - 23 March, 1987) proved to be satisfactory, except for the following comments:

8.1 POWER GENERATION: The power supplied to the instruments of the AMV by the 5.6 KVA power generator (which is included in the equipment of the van) tripped several times and was therefore replaced by a larger (10 KVA) auxiliary generator provided by the PPCD in Agra. This larger generator also enabled us to carry out simultaneous SPM measurements, and compare results obtained by the optical instrument in the van with results from a high volume sampler (a reference method).

8.2 SULPHUR DIOXIDE: The Bendix Model 8303 SO2 analyer installed in the AMV is based on the Flame Ionization Detection (FID) method, which is presently considered to be the most reliable SO2 measurement method. However, it has two drawbacks as far as mobile measurements are concerned:

(1) After it has been turned on, it requires a prolonged time for stabilization untill ready for measurement. In the case of the UPK van, it took about 1.5 hours after turning the equipment on before useful SO2 data could be obtained.

(2) This SO2 instrument requires for its operation a continous supply of hydrogen, which makes it much bulkier and heavy, and less suitable for mobile measurements.

8.3 SUSPENDED PARTICULATE MATTER: It should be borne in mind that although the KTN Dust Monitor (Sigrist Photometer) installed in the AMV provides a continous output suitable for automatic data reduction, a fact that is extremely important for a mobile station, it is not a reference method instrument neither equivalent to the reference method. There is quite a lot of evidence that results obtained by optical instruments do not correlate well with rsults obtained by the reference method (i.e., the HiVol method). A similar problem exists also with the other continuous and automatic dust monitors available on the market (such as the Beta-gauge instruments).

8.4 SPARE PARTS: The lack of spare parts was not felt yet during the Agra project. However, it is strongly recommended that PCRI obtains a stock of vital spare parts required for the operation of the AMV. The following spare items were also deemed necessary:

- Spare ignition keys and lock keys for the AMV.

- Spare instruction manuals for the AMV's instrumentation (including the missing flow chart for the callibration system, and English replacement of some of the instructions given in German).

- Spare permeation tubes for SO2 callibration and gas cyllinders for CO, NO, and CH4 callibration. It must be emphasized that without a fresh supply of callibration gases every six months, the AMV cannot be operated. However, Indian-made permeation tubes and callibrated gas cyllinders are not available, and import licenses for these items cannot presently be obtained. Dr. M.K. Hussein (SIDFA, UNDP,Delhi) suggested as a temporary solution to this problem to purchase these relatively inexpensive items (less than US$ 10,000) through UNDP in Delhi.

8.5 DATA ACQUISITION SYSTEM: Some minor changes in the computer software of the Data Acquisition System (DAS) are necessary (see Par. 7.9):

- Reduce the number of significant figures in the data output.

- Correct title of data table.

- Enable the operator of the AMV to obtain the average results of measurements for any, and the whole sampling period. Presently, results can be presented for only one pre-selected averaging period.

It is suggested that the source of the program should be made available to the PCRI staff so they can make these changes, and others in the future, by themselves.

8.6 LOGISTICS: The logistic aspects of a field opeation such as the Agra AP monitoring project have to be carefully planned ahead by PCRI staff according to the experience gained at the Holli operation. Particularly, the aspects of transportation of the AMV to its destination, food and spare parts supplies at the project site, and maintenance requirements of the AMV and its instrumentation during the operation have to be considered.

8.7 AIR CONDITIONER: On one occasion condensed AC water was dripping inside the instrument cabin.

9. SELECTED TOPICS

9.1 Emission Rates from Iron Cupolas

For a rational management of AQ, an inventory of the quantities of pollutants emitted into the atmosphere in a given region is required (a-so called "emission inventory"). The iron foundry industry has been identified as the most numerous and biggest emitter of pollution in the Agra area, in two surveys carried out by the CBPCWP in 1981 and by the PPDC in 1986. The recent PPDC survey, carried out on behalf of the Agra Iron Foundries Association, includes 115 iron foundries located in Agra and its neighbourhood. According to this survey, the output of this industry is estimated at about 135,000 tons (metric) of iron per year, whereas its coke consumption is about 37,000 tons/year.

It is therefore important to obtain reliable figures as to the actual emission rates from the various iron cupolas operating in the area.

Stack sampling is the direct and obvious method of determining these emission rates. However, the operating conditions of the cupolas in Agra (i.e., high flue gas exit temperatures, lack of stack sampling ports or lack of stacks altogether) do not allow to use the standard stack sampling methods.

It was suggested to use the upwind-downwind monitoring method developed for fugitive dust emissions (Budianski, 1980; MRC, 1978; PEDCo, 1977; IERL, 1976), to estimate from ambient AQ measurements the strength of cupolas as an emission source in Agra.

9.2 Ambient Air Quality Mathematical Modeling

Single AQ monitoring stations, as well as large AQ monitoring networks, supply data that represents only the adjacent neighbourhood of the monitors. To obtain a description of the pollution concentration in the whole area (in the form of isopleths or concentration contours), the data regarding the pollution in the spaces between the monitors has to be interpolated.

Obviously, the denser the network and the more stations available, the les interpolations are required. On the other hand, the number of AQ monitoring stations is always limited, either by pratical or budjetary contraints.

To obtain a reliable interpolation of the AQ data, it is customary to use mathematical computer models which simulate the pollution dispersion and transport in the atmosphere. The measured pollution concentrations obtained from the AQ stations are utilized to verify and validate the model results. Thus the AQ dispersion models and the AQ monitoring stations complement each other.

Many AQ dispersion models were developed to simulate the various environmental conditions and pollution emissions: Flat terrain, complex topography, urban areas and industrial areas, single and multiple (point) sources, traffic (line source), photochemical (reative) and stable (nonreactive) pollutants (see: Turner, 1970; and Hanna et al., 1982; #4 and 5 in App. 12.6, and also: Benarie, 1980).

A package of useful mathematical AQ dispersion models called UNAMAP has been developed by, and for the USEPA, and checked by them for reliability and accuracy. Most of the models included in the package are recommended by the USEPA for use as tools to show compliance with AQ requiremens in USA regulations. UNAMAP models are periodially updated and only recently the sixth version of UNAMAP was made available to the public. UNAMAP models were written for a large mainframe computer (UNIVAC) in FORTRAN computer language, but the most common of them are commercially available also in versions suitable to machines of the type IBM-XT.

For independent AQ computer modeling the following hardwareand software is required:

- an IBM-XT personal computer or a good hardware-compatible IBM-XT. The hardware configuration should include a 10-20 MByte disk drive, a 2-diskette drive, a printer, a plotter and a monitor.

- the software package should include popular scientific languages adapted to PCs such as: Extended BASIC, FORTRAN, C, PASCAL, and some data base (DBase) software. Very often, much of this software is supplied with the PC itself. The software of the AQ dispersion models have to be purchased seperately. Useful models are:

CRSTER - Estimates groud level concentrations resulting from up to 19 co-locatedelevated stack emissions (price:US$180-250)

RAM - A short-term multiple-source model that estimates the concentrations of stable pollutants from urban and area sources (price: about US$500)

HIWAY-2 - Computes the hourly concentrations of non-reactive pollutants downwind of roadway (price: US$120-150)

VALLEY - This algorithm is a Gaussian model designed for estimating either 24-hour or annual concentrations from up to 50 point and area sources located in a complex topographic terrain (price: US$200).

User's Guides fo all UNAMAP models are available from the USNTIS (US Dept. Commerce, Springfield, VA, USA).

9.3 Ambient Air Quality Standards vs. Emission Standards

It is now common knowledge that the atmosphere is a finite resource, in the sense that its capacity to absorb and disperse pollutants injected into it is quite limited. Therefore, the atmosphere, like any other limited resource, requires rational management that will enable the allocation of this resource to its many users (Suess & Craxford, 1976, see: #21 in App. 12.6).

Two very important tools for AQ management are ambient AQ standards and emission standards:

- AMBIENT AIR QUALITY STANDARDS are the legally allowed concentrations of pollutants in the ambient air averaged over specified periods of time (Newill,1976, Ch.11, Vol. 5 in: Stern, 1977, see: #1 in App. 12.6).

Ambient air is usually defined as the outdoor atmosphere in non-industrial areas and the air outside-of-the-fence of plants in industrial areas.

The quality of the ambient air is determined by air quality monitoring instruments. The concentrations of pollutants measured by these instruments are compared with ambient AQ standards (also known as IMMISSION STANDARDS). National AQ standards differ widely from one country to country. In some countries, different AQ standards exist for different parts of it (see App. 12.12: The AQ standards set by the Federal Government of India are different than those set by the State of U.P.). A comprehensive compilation of ambient AQ standards in effect over the world has been prepared by A.C. Stern and is included as Ch. 13, in Vol.5 of the well-known encyclopedia on air pollution edited by him (Stern, 1977, see: #1 in App. 12.6).

A draft document published recently by the WHO suggests ambient AQ standards for 27 different pollutants (WHO, 1986). Once this document is published in its final form,it is sure to become a guideline for internationally accepted levels of pollutant concentrations permitted in the atmosphere.

- EMISSION STANDARDS are another important tool required for AQ management. They are the rates of pollution legally allowed to be emitted into the atmosphere through the stack or ventilation vent of the pollution source. Like ambient standards, they differ from one country to another. However, no attempt has yet been made to reach internationally agreed upon emission standards. USEPA has published a compilation of very useful data, which describe the typical emission rate of pollutants according to the type of industrial activity (the so-called "emission factors") (USEPA, 1977, see: #10 in App. 12.6).

9.4 Environmental Impact Assessment (EIA)

(1) EIA is a planning process usually employed before, or during, the permit procedures of either entirely new projects to be built, or in the case of major alterations and expansions of existing projects. One of the main purposes of the EIA process is to chose the optimum site, from an environmental point of view, for the planned project. A list of some literature references on the EIA process is given in App. 12.13.

(2) The EIA process involves the identification of the parameters of the project known in advance to affect, adversely or otherwise, the environment in a defind area around the project and assessment of their environmental impact.

(3) Typical types of new projects which require EIA's are:

- Thermal power plants
- Oil refineries
- Chemical industrial plants
- Petrochemical industrial plants
- Cement plants
- Air ports
- Sea ports
- Railway tracks
- Major roads
- Mineral quarries (especially open mines)
- Shopping centers
- Sport stadiums
- Waste disposal sites
- Water dams
- Water cannals
- Hospitals
- Schools
- New resindential areas

(4) The EIA process involves assessment of the project regarding air pollution, noise pollution, water pollution (above and below the ground), sea pollution, pollution by solid wastes (including toxic wastes), pollution by sewage, thermal pollution and aesthetics.

(5) The EIA process for air quality involves the following methods:

- Establishing the background air quality (i.e., the AQ without the new or proposed activity) by carrying out AQ monitoring or by evaluating existing monitoring results.

- Establishing the meteorological characteristics of the site affecting the dispersion and transport processes of the emissions (by monitoring or evaluating existing meteorological data).

- Establishing the existing emission rates in the area, and also future trends of existing and new sources other than the project itself.

- Choosing a good mathematical or physical dispersion model suitable to the conditions of the project.

- Using the above data to verify the accuracy of the chosen model and as input data for the model.

- Estimate the air quality when the project is in operation, using the verified dispersion model.

- Evaluate the future air quality vs. AQ standards (see Sec. 9.3).

- If projected AQ is not adequate, seek solutions to reduce emissions from the project (or from other activities in the area), or enhance the atmospheric dispersion.

(6) Often the conclusions and recommendations resulting from the EIA process are made mandatory by including them in the permit issued by the authorities to the initiators of the project.

9.5 Site Selection for the Air Monitoring Van

Most guidelines for selection of sites for air quality monitoring stations refer to stationary stations and are not suitable for a mobile station such as the AMV owned by PCRI (see for example: WHO/WMO,1977, #23 in App. 12.6). For a mobile AQ station the following siting guidelines are suggested:

(1) Site the AMV first downwind from the polluting source affecting the area, then, on the upwind side. The distance of the mobile station from the source should be at least 3 timesthe height of the stack or vent of the source above ground level.

(2) In a populated area, choose a site that is downwind from the dominant pollution source in the area.

(3) Site the AMV at least 25 m away from domestic chimneys and absorbing surfaces (such as trees or buildings).

(4) Site the AMV on a level surface, off the road (so as not to disturb the local traffic) and in a quiet place (where minimum disturbances from the local population are to be expected).

(5) A rough idea regarding the dominant wind direction can be obtained from the synoptic weather map published daily in the Delhi "The Statesman", and also with the aid of the sensor installed in the AMV.

6) In order to be able to describe the AQ of a given site, a full year of continuous data is desirable. This data would reflect seasonal changes in the atmospheric dispersion parameters, which affect the pollution concentrations in the air. This is one of the reasons for establishing stationary, rather than mobile , AQ stations.

However, one can get quite a good idea about the AQ of a given site using a mobile station for much shorter periods of time. The duration of the sampling at a given site should always be at least one full hour (to allow comparison of the measurement with the relevant short-term AQ standard), but much longer periods are preferred (3 hours or more).

It is advisable to obtain air quality data for three periods of the day:

- In the afternoon (NOX and O3)
- At night (under stable atmospheric conditions)
- In the morning.

(7) Place the generator downwind from the AMV.

9.6 Air Pollution Measurements Inside and Around Industrial Plants

In two of the recent projects the PCRI AP team was engaged with (namely, the Agra Project described in Sec. 5, and the HEEP Project, see App. 12.14), the problems were related to industrial activity. It can be expectd that in the future too a large proportion of PCRI AP monitoring and environmental assessment will be concerned with problems inside and around industrial plants, and that the PCRI staff will be involved with measurement of ambient conentrations of emmissions typical to industrial processes (Davidar, 1985). It is therefore recommended that the PCRI AP team acquires the expertise to measure atmospheric concentrations of pollutants such as organic compound vapors (OCVs) (also known as volatile organic compounds - VOC), volatile inorganic chemicals, and volatile compounds of metals, using internationally accepted standards and methods.

A relevant list of some of these standards includes (see

App. 12.15):

(1) Activated charcoal for the analysis of OCVs (ASTM D-3687-84);
(2) Gas chromatographic methods for analysis of atmospheric C1-C5 hydrocarbons (ASTM D-2820-72[1978]);
(3) Detector tubes for chemicals in the air (ASTM D-4490-85);
(4) Atomic absorption for measuring atmospheric concentrations of metals in workplace (ASTM D-4185-83).

The PCRI AP team should also acquaint itself with the follcwing general ASTM standards:

(1) Definition of AP analysis terms (ASTM D-1356-73a);
(2) Recommended practices for atmospheric sampling and analysis of gases and vapors (ASTM D-1605-60[1979]);
(3) General ambient air analysis procedures (ASTM D-3249-79);
(4) Standard practice for permeation tube callibration techniques (ASTM D-3609-79);
(5) Standard practice for evaluating AP laboratories (ASTM D-3614-81);

Of importance are also the ASTM standard on the use of Ringelmann Charts for black smoke emission measurements (ASTM D-4096-82),the list of threshold limit values (TLVs), which define permissible levels of AP in occupational environments (ACGIH, see: #18 in App. 12.6) and the ASHRAE standard concerned with accepted levels of indoor air pollution (ASHRAE, 1981, see: #19 in App.12.6). It should be mentioned that the existing ASHRAE standard, published in 1981 (# 62-1981), is now being revised and the new standard, when published, can be expected to be substantially different.

10. CONTINUATION OF MISSION DP/IND/83/008

It was decided on the 26.3.87. with Prof. Mahajan and Mr. Gupta that the mission will be continued in July, 1987 and some or all of the following projects will be persued:

(1) AP problems of the Bhatinda Thermal Power Plant in Punjab;
(2) AP problems of the Badarpur Thermal Power Plant near New Delhi;
(3) Application of mathematial AQ dispersion Models to EIA procedures;
(4) Development of control technologies for the Agra foundries, based on the data collected by PCRI during the Agra Project, as described in Sec. 5.

11. REFERENCES

- Benarie M.M., 1980: Urban Air Pollution Modelling, MacMillen Press, London, 405pp.

- Beloin N.J. & F.H. Haynie, 1975: Soiling of Building Materials, JAPCA, 25(4):399-400.

- Budianski S., 1980: Wanted: Fugitive Emissions, ES&T, 14(8):904-95.

- CBPCWP, 1981: Inventory and Assessment of Pollution Emissions in and Around Agra - Mathura Region (Abridged), Control of Urban Pollution Series: CUPS/7/1981-82, Central Board for the Prevention and Control of Water Pollution (CBPCWP), New Delhi, India.

- Cheng R.J. & R. Castillo, 1984: A Study of Marble Deterioration at City Hall , Schenectady, New York, JAPCA, 34(1):15-19.

- Cheng J.R., J.R. Hwo, J.T. Kim & S. Leu, 1987: Deterioration of Marble Structures: The Role of Acid Rain, Annal. Chem. 59(2):104A-105A.

- Davidar D., 1985: Beyond Bhopal; The Toxic Waste Hazard in India, Ambio, 14(2):112-116.

- Del Monte M., C. Sabbioni & O. Vittori, 1981: Airborne Carbon Particles and Marble Deterioration, Atm. Env., 15:645-652.

- Feddema J.J. & T.C. Meierding, 1987: Marble Weathering and Air Pollution in Philadelphia, Atm. Env., 21:143-157.

- Gauri K.L., 1978: The Preservation of Stone, Scientific American, June, 1978:104-110.

- Gauri K.L. & G.C. Holdren, 1981: Pollutant Effects on Stone Monuments, ES&T,15(4):386-390.

- Graedel T.E. & R. McGill, 1986: Degradation of Materials in the Atmosphere, ES&T, 20(11):1093-1100.

- IERL, 1976: Technical Manual for the Measurement of Fugitive Emissions: Upwind-Downwind Sampling Method for Industrial Fugitive Emissions, Industrial Environmental Research Laboratory (IERL), Document #EPA-600/2-76-089a, USEPA, NC, USA.

- Khemani L.T., G.A. Monin, M.S. Naik, P.S. Prakasarao, R. Kumar & B.H.V. Ramana Murty, 1985: Impact of Alkaline Particulates on pH Rainwater in India, Water, Air,Soil Poll., 25:365-376.

- Kucera V., 1976: Effects of SO2 and Acid Rain Precipitation on Metals and Anti-Rust Painted Steel, Ambio, 5:243-248.

- MRC,1978: Source Assessment: Crushed Stone, Appendix B: Sampling Equipment, Procedures, and Analysis, Monsanto Research Corp. (MRC), Document #EPA-600/2-78-004L, USEPA, NC, USA.

- PEDCo, 1977: Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions, Appendix D: Example Upwind/Downwind Test Plan for Hypothetical Cement Plant, Document #EPA-450/3-77-010, USEPA, NC, USA.

- Subramanian V. & K.K. Saxena, 1980: Chemistry of Monsoon Rainwater at Delhi, Tellus, 32:558-661.

- Yocom J.E., 1979: Air Pollution Damage to Buildings on the Acropolis, JAPCA,29(4):333-338.

- WHO, 1986: Air Quality Guidelines - Final Unedited Draft, World Health Organization (WHO) Regional Publication, Copenhagen.

APPENDIX 12.1

Program Executed During Field Mission to India:

8-28 March, 1987

- Sunday, 8 March:

  Left Jerusalem for Vienna

- Monday, 9 March:

  Morning: Arrangement (through UNIDO) for visa to India
  Afternoon: Briefing in Dr. Maltezou's office, UNIDO.

- Tuesday, 10 March:

  Morning: Briefing (see App.12.3).
  Afternoon: Briefing, Obtaining visa to India.

- Wendnesday, 11 March:

  Left Vienna to Delhi.

- Thursday, 12 March:

  Morning: Reached Delhi, transferred to Hotel "Claridges", met Dr. M.K. Hussein (SIDFA) and Mr. Sat Pal From UNDP, Delhi.
  Afternoon: Transferred to Hotel "Samrat", Delhi, and met Prof. S.P. Mahajan (Head, PCRI) and Dr. M.K. Hussein (see App. 12.7).

- Friday, 13 March:

  Morning: Left Delhi by car to Haridwar.
  Afternoon: Reached Haridwar, met Prof. Mahajan, Mr. A.K. Gupta and the PCRI air pollution team, discussed work plan (see App. 12.2).

- Saturday, 14 March:

  Morning: Inspected the UPK mobile AP monitoring van and carried out measurments with the van at CFFP (in the BHEL campus in Haridwar).
  Afternoon: Continuation with measurements at CFFP.

- Sunday - Monday, 15 - 16 March:

  Holli Feast

- Tuesday, 17 March:

  Morning: Lectures to the PCRI AP team on: Conversion Factors, Clean and Polluted Atmospheres, Air Quality Standards, Site

Selection for an Air Monitoring Van, and the Air Quality Sampling Plan for Agra (Sec. 9).
Afternoon: Preparation of the Equipment for the Agra Air Monitoring Project.

- Wednesday, 18 March:

Morning: Left Haridwar by car to Delhi, met Dr. Hussein at UNDP.
Afternoon: Arrived in Agra, meeting with Mr. A.K. Gaur and Prof. Mahajan at PPDC office, checked into Hotel "Tarandeep", Agra.

- Thursday, 19 March:

Morning: AQ monitoring at the PPDC site, near the Nagra Foundries.
Afternoon: Continuation of AQ monitoring at PPDC, obtaining a bigger (10KVA) generator for the AP monitoring van, and checking into the Hotel "U.P. Bungalow", Agra.

- Friday, 20 March:

Morning: AQ Monitoring at Sikandra.
Afternoon: AQ monitoring at Taj Mahal.
Evening: AQ monitoring at Taj Mahal.

- Saturday, 21 March:

Morning: AQ monitoring at "Metal-Cast" Foundry, Agra, inspection of the foundry with the superviser of the foundry (Mr. S.B. Agarwal).
Afternoon: AQ Monitoring at Fort Agra.

- Sunday, 22 March:

Morning: Meeting with Mr. Gaur and Mr. Gupta (see App. 12.8).
Afternoon: AQ monitoring at the Belanganj Goods Shed and inspection of the "Raj Pattern Makers and Founders" and "Raman Foundries" with the owners Mr. R. Mohan and Mr. Raman (see App. 12.7).

- Monday, 23 March:

Morning - Afternoon: Left Agra to Haridwar by car.

- Tuesday, 24 March:

Morning: Discussing with PRCI AP staff their draft report: "AP, Humidity and Noise in the HEEP Storage (see App. 12.14).
Afternoon: Discussing with PCRI AP staff a detailed outline for the preparation of the Agra AP monitoring report (see App. 12.11).

- Wednesday, 25 March:

  Morning - Afternoon: Discussing with APCR AP staff the suggested training courses and equipment purchased, or to be purchased by PCRI (see Sec. 6 and Sec. 7).

- Thursday, 26 March:

  Morning: Lecture to PCRI AP staff on AP Modelling, Plume Rise Equations, Emission Standards and Environmental Impact Assessment (see Sec. 9).
  Afternoon: Summary meeting with Prof. Mahajan and Mr. Gupta.

- Friday, 27 March:

  Morning: Left Haridwar to Delhi by car.
  Afternoon: Metting with Mr. Sat Pal, UNDP, Delhi, and debriefing by Dr. M.K. Hussein (SIDFA, UNDP, Delhi).
  Evening: Meeting at the Hotel "Claridges" with Dr.Ing. J. Marcinkowski (UNIDO Expert on iron cupola operation) (see App. 12.7).

- Saturday, 28 March:

  Morning (early): Left Delhi to Vienna.
  Afternoon: Debriefing in Vienna by Dr. S.P. Maltezou (at the loby of the Hotel "Hilton").
  Evening: Left Vienna to Tel-Aviv.

- Sunday, 29 March:

  Morning: Arrival in Jerusalem.

APPENDIX 12.2

Work Plan for Dr.M. Graber, Air Pollution Control Expert (13.3.87)

Date		Work Plan
13.3.87	(a)	Visit to various laboratories of PCRI including mobile air lab.
	(b)	Discussions with the executives regarding monitoring of stack emissions.
14.3.87	(a)	Training regarding volumetric methods for CO, Hydrocarbons etc.
	(b)	Stack emission monitoring at TPS HEEP Hardwar.
	(c)	Monitoring of ambient air quality using Air Van.
17.3.87	(a)	Discussion on Bhatinda TPS Project.
	(b)	Discussion on Agra Foundries Project.
	(c)	Finalization of prerequisites for the projects.
	(d)	Training on mathematical modelling.
18.3.87 to 20.3.87		Study of foundry problems at Agra, and back to Hardwar.
21.3.87	(a)	Submission of Report on Agra Project.
	(b)	Training in mathematical modelling with respect to ambient air quality dispersion models, Gaussian models, forecasting.
23.3.87	(a)	Training on ambient air quality monitoring.
	(b)	Foundry pollution problems of CFFP.
24.3.87 to 25.3.87		Study of monitoring work at Bhatinda TPS, and back to Hardwar.
26.3.87	(a)	Submission of report on Bhatinda Project.
	(b)	Discussion on present equipment and suggestions for enhancing the present capabilities.
	(c)	Finalization of report.
27.3.87		Departure to Delhi and meeting at UNDP.

APPENDIX 12.3

To: Prof. S.P. Mahajan
Head, PCRI

From: Dr. M. Graber
UNIDO Expert

Date: 25 March, 1987

Sub: Problems and Issues Raised by Dr. S. Maltezou, UNIDO, Vienna, Regarding Project DP/IND/83/008

While being briefed for my mission to India in Vienna on 10 March, 1987 Dr. Maltezou raised the following problems and issues regarding Project DP/IND/83/008:

1. UNIDO requires urgently Nomination Forms for Austroplan trainees. They can be obtained from the SIDFA in Delhi.

2. UNIDO would like to get the details of the number of PCRI support staff, as of March 1987, and that planned for August 1987 (technical support staff and scientific staff).

3. UNIDO requires urgently the requisition form, which includes neutral specifications (i.e., no mention of suppliers) for the stack sampling van, signed by you. Dr. Maltezou suggests to clear the finances regarding the purchasing of the van with Dr. Hussein at UNDP, Delhi.

4. Dr. Maltezou suggests to speed up recruitment of UNIDO experts. UNIDO is worried about the slow pace of this process. All experts have to be cleared by India before August 1987, in order to be able to field them still in 1987. Otherwise, the expert program will have to be rephased. This issue concerns Dr. Weinstein, Dr. Kessler, Dr. Biswas and myself.

5. It was suggested that Dr. Biswas be invited as an Ad Hoc consultant rather than a UNIDO expert.

6. It was suggested that all equipment purchased (the stack sampling van and computers especially) should be cleared before August, 1987, for the reasons stated above.

7. Regarding the "Modern Technologies in Waste Treatment Project" (a pipeline project), UNIDO would like to know:

(a) The number of specialists, and their speciality, proposed by PCRI to support this project.
(b) Suggestions to enhance the efficiency of communications between PCRI and UNIDO/Vienna, and to speed up the decision making process and approval procedures (without sacrifying correct bureaucratic procedures).
(c) Require a PCRI commitment to train in PCRI people from other Asian countries.

8. Dr. Maltezou suggests that Prof. Mahajan and the Chairman of BHEL meet with UNIDO officials in Vienna sometime in May 1987 to discuss all modalities, as well as streamline implementation for 1987 and 1988.

9. Dr. Maltezou suggests that the undersigned reviews:

(a) All AP equipment specifications still pending.
(b) AP training courses still pending (mainly, Austroplan).
(c) Requirements for further equipment.
(d) Requirements for further training (in India and abroad).

10. It was suggested that Dr. Graber, while on mission to India, provides:

(a) AP instruction material.
(b) Ad Hoc consulting for industry.
(c) Assistance in preparing AP reports.

Sincerly yours

(M. Graber)

CC: Dr. S.P. Maltezou, UNIDO, Vienna
Dr. M.K. Hussein, SIDFA, UNDP, Delhi

APPENDIX 12.4

PCRI Air Pollution Support Staff - As of March, 1987

AIR POLLUTION MANAGER:	A.K. Gupta
AIR POLLUTION ENGINEERS:	Anil Jaine Avnish Goel M.K. Ghosh Ambrish Goel Pawan Malik
AIR POLLUTION SUPERVISOR:	R.l. Singhal
AIR POLLUTION LABORATORY ASSISSTANTS:	Kennedy Singh Gussain Chaterpal Singh Khosla

APPENDIX 12.5

List of Air Pollution Instrumentation and Equipment at PCRI as of March, 1987

1. Air Monitoring Equipment

1.1 UPK Air Monitoring Van, including the following items:

(1) Mercedes Model 809 van
(2) Air Conditioner
(3) Solar Radiation Detector Model 4.5DSE - 53CR
(4) Onan Corp. Diesel Power Generator (5.6 KVA)
(5) 10m Collapsible Meteorological Mast
(6) Thies-Clima Wind Speed and Direction Detectors
(7) KTN Sigrist Dust Monitor Photometer
(8) Glass Input Gas Funnel
(9) Air Cleaner (for vented air)
(10) Compressor and Zero Air Vessel
(11) Thies-Clima Hair Hygrometer
(12) Thies-Clima Barotransmitter
(13) Teledyne Energy Systems Model HG501 Hydrogen Generator
(14) Bendix Model 8101 NO/NOX Analyzer
(15) Bendix Model 8202 Reactive Hydrocarbon Analyzer
(16) Bendix Model 8002 Ozon Analyzer
(17) Bendix Model 8303 Total Sulfur Analyzer
(18) UNOR Model 6N IR CO Analyzer
(19) UPK Series 1000 Gas Callibration System (Permeation tubes for SO2, Gas Cyllinders for NOX, CO, THC, and a HITEC Mass Flow Meter)
(20) Data Acquisition System (Delpnin System):
- Commodor Model C-64 PC
- Monochrome VDU
- Dual 5.25" Floppy Disk Drive
- Epson Model RX80 Printer
- Interface to the Instruments of the Van
(21) Instruction Manual for Instruments of the Van.

1.2 Teco Model 43 SO2 Fluorescent Analyzer: One instrument.
Comment: Currently out of order due to a failure of a printed circuit.

1.3 Teco Model 145 Permeation Callibrator and Zero Air Supply for SO2 Teco Model 43: One instrument.

1.4 Stroehlen Model HVS150 HiVol (circular filter,10" diameter): Six instruments.

1.5 Epson Model RX80 Recorders: Six instruments.
Comment: Intended for the Stroehlen HiVols.

1.6 Stroehlen LoVol: Six instruments.
Comment: Faulty instruments. They were sent back to supplier four months ago.

1.7 Teco Model 14A NOX ANALYZER: One instrument.

1.8 Teco Model 100 NOX Generator: One instrument.

1.9 Teco Model 102 NO Callibrator: One instrument.

1.10 Teco Model 111 Zero Air Supply for NOX Teco Model 14A: One instrument.

1.11 SICO (Indian Made) Voltage Regulators: Several Instruments.

2. Meteorological Monitoring Instruments (Weather Station)

2.1 Thies-Clima Automatic Rainwater Gauge.

2.2 Thies-Clima Relative Humidity Sensor.

2.3 Thies-Clima Solar Radiation Sensor.

2.4 Thies-Clima Ambient Temperature Sensor.

2.5 Thies-Clima Wind Speed/Direction Sensor.

2.6 Thies-Clima Barometric Pressure Gauge.

2.7 Data Acquisition System (Delphine System):
- Commodore 64 PC
- Dual 5.25" Floppy Disk Drive
- Epson RX80 Printer.

Comment: The equipment at the weather station has been installed only recently by the supplier. There is as yet no power supply to the equipment.

3. Stack Sampling Equipment

3.1 Stack Sampling Monitors: 2 instruments.

3.2 Thermogun: 1 instrument.

APPENDIX 12.6

A List of Useful Journals and Books on Air Pollution

Journals

1. Journal of the Air Pollution Control Association (JAPCA), Pittsburgh, PA, USA, ISSN 0002-2470.

2. Environmental Science & Technology (ES&T), A Journal of the American Chemical Society, Washington D.C., USA, ISSN 0887-0624.

3. Atmospheric Environment, Pergamon Press, Oxford, England, ISSN 0004-6981.

Books and Reports

1. Stern A.C.(Editor), 1977: Air Pollution (5 Volumes), Academic Press, New York, ISBN 0-12-666601/2/3/4/5-6/4/2/0/9 (Available at PCRI).

2. Stern A.C. (Editor), 1986: Air Pollution (3 Supplement Volumes), Academic Press, New York.

3. Seinfeld J.H., 1986: Atmospheric Chemistry and Physics of Air Pollution, J. Willey, New York, 738p, ISBN 0-471-82857-2.

4. Hanna S.R., G.R. Briggs & R.P. Hosker, 1982: Handbook on Atmospheric Diffusion, Document # DOE/TIC-11223, USDoE, Washington D.C., USA, ISBN 0-87079-127-3.

5. Turner D. B., 1970: Workbook of Atmospheric Dispersion Estimates, Document # AP-26, USEPA, NC, USA.

6. NEERI: Air Quality Monitoring - A Course Manual, The National Environmental Engineering Research Institute (NEERI), Nehru Mary, Nagpur, 440020, India (available at PCRI).

7. Crawford M., 1976: Air Pollution Control Theory, McGraw-Hill, New York, 624p, ISBN 0-07-0134990-1.

8. Cheremisinoff P.N. & R.A. Young (Editors), 1975: Pollution Engineering Practice Handbook, Ann Arbor Science Publication Inc., xxxp, ISBN 0-250-40075-8.

9. Noll K.E. & W.T. Davis, 1976: Power Generation - Air Pollution Monitoring and Control, Ann Arbor Science Public., Ann Arbor, Mich., ISBN 0-250-40118-5.

10. USEPA, 1977: Compilation of Emission Factors (3rd Edition), Document # AP-42, PB 275 525, USEPA, NC, USA.

11. Danielson J.A. (Editor), 1973: Air Pollution Engineering

Manual (2nd Edition), Document # AP-40, USEPA, NC, USA.

12. USEPA, 1986: Guidelines on Air Quality Models (Revised), Document # EPA-450/2-78-027R (July 1986), USEPA, Washington D.C., USA.

13. Plate E.J. (Editor), 1972: Engineering Meteorology, Elsevier, Amsterdam, 740p, ISBN-444-41972-1.

14. Dobbins R.A., 1979: Atmospheric Motion and Air Pollution, J. Wiley, New York, 323p, ISBN 0-471-21675-5.

15. Mahajan S.P., 1985: Pollution Control in Process Industries, Tata McGraw-Hill, New Delhi, 277p.

16. Shreve R.N. & J.A. Brink, 1977: Chemical Process Industries, 4th Edition, McGraw-Hill,New York, 814p, ISBN 0-07-057145-7.

17. Weast R.C. & M.J. Astle (Editors), Annual Editions: CRC Handbook of Chemistry & Physics, CRC Press, FA, USA, ISBN 0-8493-0549-8.

18. ASTM, Annual Edition: ASTM Standards, Section 11: Water and Environmental Technology; Vol. 11.03: Atmospheric Analysis, Occupational Health and Safety, The American Society for Testing and Materials (ASTM), Philadelphia, USA, ISBN 0-8031-0686-6.

19. ACGIH, Annual Edition: Threshold Limit Values (TLVs) for Chemical Substances in Workroom Air Adopted by ACGIH, the American Conference of Governmental Industrial Hygienists (ACGIH), Cincinnati, USA, ISBN 0-936712-34-1.

20. ASHRAE, 1981: Ventilation for Acceptable Indoor Air Quality, ASHRAE 62-1981, The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

WHO Publications

21. Suess M. J. & S.R. Craxford (Editors), 1976: Manual on Urban Air Quality Management, WHO Regional Publication #1, Copenhagen.

22. WHO/UNEP, 1976: Selected Methods of Measuring Air Pollutants, WHO Publication #24, Geneva.

23. WHO/WMO, 1977: Air Monitoring Programme Design for Urban and Industrial Areas, WHO Publication #33, Geneva.

24. WHO/UNEP, 1980: Analyzing and Interpreting Air Quality Data, WHO Publication #51, Geneva.

25. WHO/UNEP, 1982: Estimating Exposures to Air Pollutants, WHO Publication #69, Geneva.

APPENDIX 12.7

United Nations Industrial Development Organisation

UNIDO

DR. M. KAMAL HUSSEIN
Senior Industrial Development Field Advisor

Tel. Off. 690410
Res. 634756

UNDP, 55, LODI ESTATE,
NEW DELHI-110003

SAT PAL
ASSTT. PROGRAMME OFFICER
UNITED NATIONS DEVELOPMENT PROGRAMME

OFFICE :
55, LODI ESTATE
NEW DELHI-110003
TEL. : 690410-699174

RESIDENCE :
C-27, KIRTI NAGAR.
NEW DELHI-110015
TEL. : 533073

Phones: B.H.E.L. HARDWAR
PABX—324
Telex : 0585-241 & 244
Gram : BHARATELEC

Dr. N. C. TREHAN
M. Sc., D. Phil
Sr. Scientific Officer
Pollution Control Research Institute

BHARAT HEAVY ELECTRICALS LIMITED
Hardwar—249403, U.P. (India)

A. K. GAUR
Principal Director

PROCESS & PRODUCT DEVELOPMENT CENTRE
Under United Nations Development Programme
(A Government of India Society)
FOUNDRY NAGAR. AGRA-2820C? (U.P.)

Phone : 72496, 75739

Raman
M.A., A.M.I.B.F., M.I.I.F., DIP.S.S.

Chairman :
Public Relations
Agra Iron Founders' Association

The National Iron Foundry
Moti Lal Nehru Road,
A G R A - 282 004 (India)

88, North Vijay Nagar Colony
A G R A - 282 004
Phone : 73937

R. MOHAN

Raj Pattern Makers & Founders
MOTILAL NEHRU ROAD, Opp. Belanganj Goods-Shed
A G R A-282004
PHONE : 62565 • 62545 GRAM : RAJPATTERN

INSTYTUT ODLEWNICTWA — Zakład Doświadczalny
FOUNDRY INSTITUTE — Pilot Plant
GIESSEREIINSTITUT — Versuchsanstalt

Doc. dr inż. JAN MARCINKOWSKI
Dyrektor

Poland
30-418 Kraków,
ul. Zakopiańska 73

tel.: 66-08-03
telex: 32-24-31

APPENDIX 12.8

MINUTES OF THE MEETING HELD IN THE CHAMBER OF PRINCIPAL DIRECTOR, PROCESS AND PRODUCT DEVELOPMENT CENTRE, AGRA ON 22.3.1987 TO REVIEW THE PROGRESS OF THE STUDY ON POLLUTION CONTROL IN FOUNDRY INDUSTRY AT AGRA

* * * * * *

The following were present :-

1. Shri A.K.Gupta, Manager, P.C.R.I. Haridwar.
2. Shri M.Graber, UNIDO Expert.
3. Shri M.K.Ghosh, Engineer, PCRI, Haridwar.
4. Shri A.Goyal, Engineer, P.C.R.I. Haridwar.
5. Shri A.K.Gaur, Principal Director, P.P.D.C. Agra.
6. Shri A.Ramarao, Dy.Director(Met), PPDC, Agra

1. At the outset Shri A.K.Gaur, Principal Director, P.P.D.C. Agra informed the members that he had a seperate meeting with Prof. Mahajan, Dr. Graber and a few office bearers of Agra Iron Foundries Association to workout the modus operandi of the study. He mentioned, that the members had decided to conduct the ambient air monitoring tests at the following places which would help P.C.R.I. to compare the results with those to be taken, when the cupolas will be in operation at a later stage.

1. P.P.D.C. Foundry Nagar, Agra.

2. Sikandra, Agra.

3. Taj Mahal, Agra.

4. Industrial Area, Nunhai, Agra (near Metal Cast foundry).

5. Agra Fort (Power House Station crossing)

6. Belanganj Goods Shed, Agra.

Dr. Graber informed that the tests were conducted at the places mentioned above from 18.3.1987 to 22.3.1987.

2. The future course of action for monitoring the ambient values, when cupolas are in operation and as well as their stack emission was discussed and it has been decided tentatively that the study team from PCRI, Haridwar would undertake the work from

2.4.1987 to 1 [illegible].1987 in respect of 15 to 17 selected foundry units which represent the total cross section of the foundry industry at Agra. However the above dates would be confirmed by P.C.R.I. Haridwar. While monitoring the stack emission of the cupolas in selected foundry units, ambient air monitoring will also be carried out at those places, where the tests were conducted previously prior to operation of cupolas.

3. An advance team would be visiting Agra to inspect the foundries from which the tests are to be conducted and to make necessary arrangements as required for the tests.

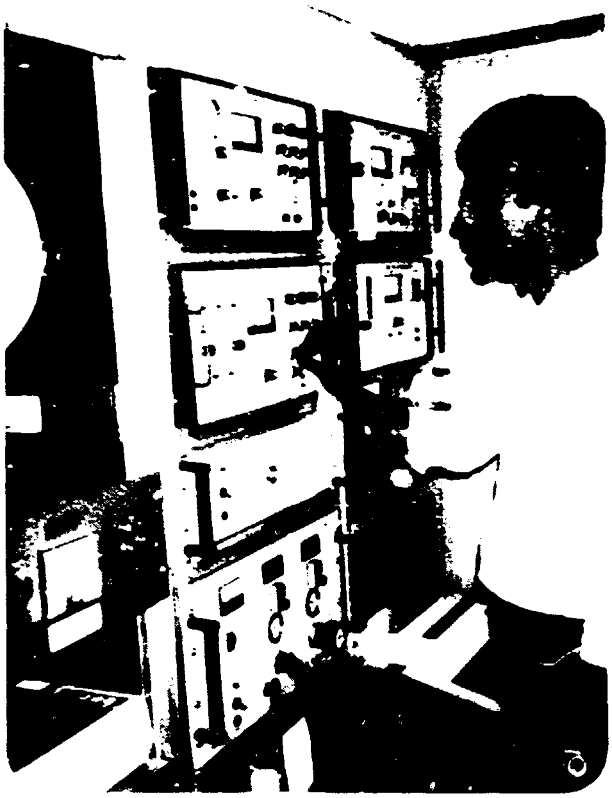
4. P.P.D.C. Agra would co-ordinate the compilation of the data from these selected foundry units and it is hoped that the data would be made available to the monitoring team by 31.3.1987.

5. P.C.R.I. would collect foundry coke samples for analysing the same.

****

APPENDIX 12.9

1. Mr. M.K. Ghosh, Engineer, from the PCRI AP team, inside the Air Monitoring Van.



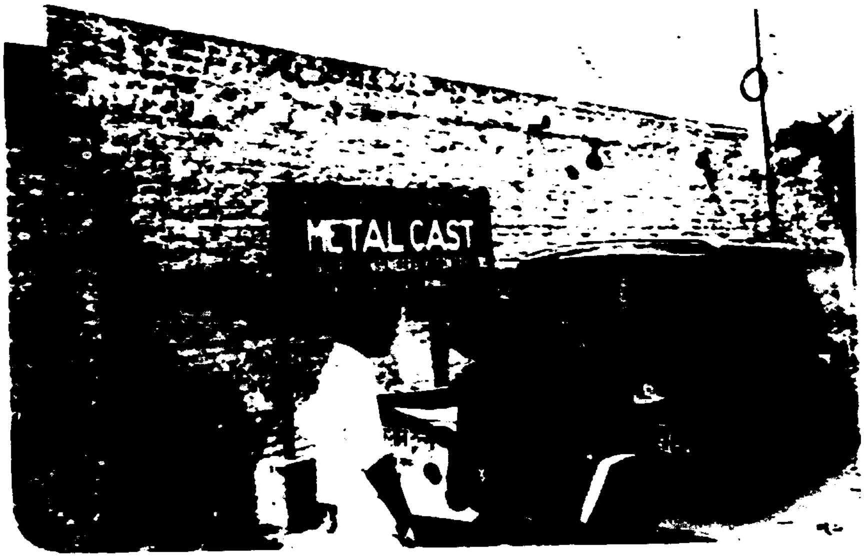
2. Mr. A. Goel, Engineer, from the PCRI AP team, inside the Air Monitoring Van.

3. PCRI Air Monitoring Van at PPDC, Agra.

4. From left to right:
Messrs. A.K. Gaur (Principal Director, PPDC), R. Mohan (Raj Pattern Makers & Founders, Agra), A. Ramarao (Dy. Director, PPDC), S.P. Mahajan (Head, PCRI), and Raman (Raman Foundries).

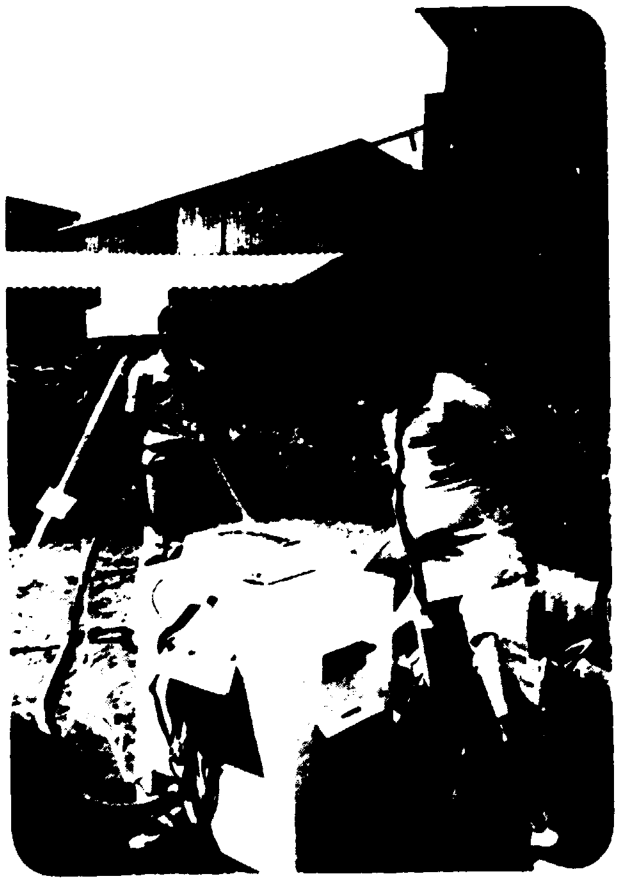
5. Air quality measurements at Sikandra (12km North-West of Agra).

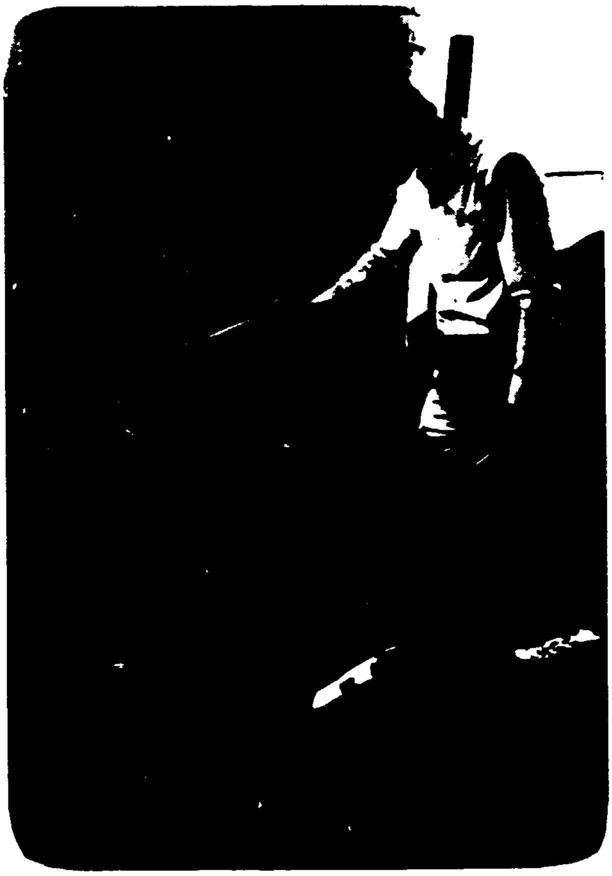
6. PCRI AP team at Sikandra.



7. Diesel power generator (1ØKVA) supplied by PPDC for the operation of the Air Monitoring Van.

8. Mr. K.S. Gussain, AP Lab. Assiss., with HiVol sampler, and S.B. Agarwal, Superviser of Metal-Cast Foundries, Agra.





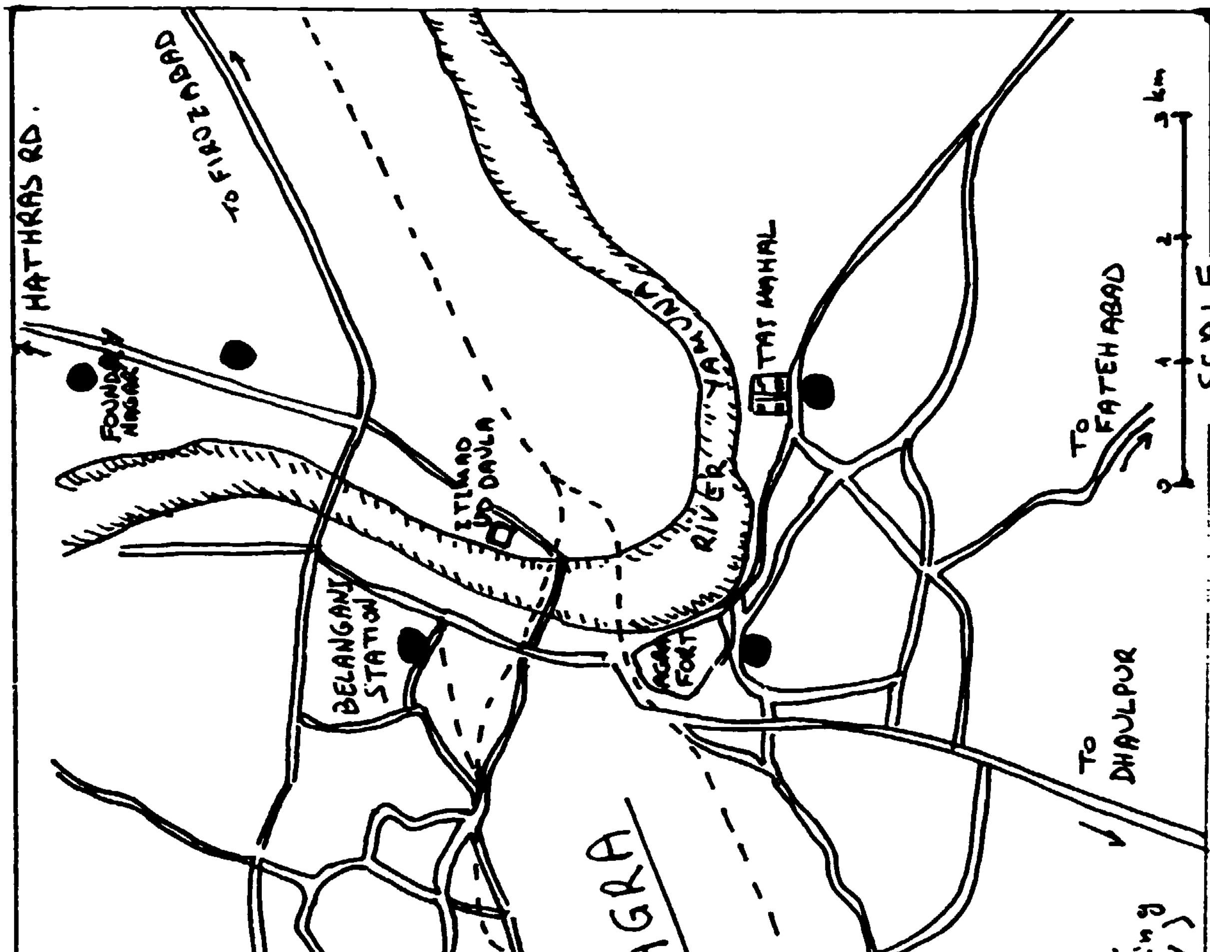
9. Mr. M.K. Ghosh looking through the charging port into the cupola of Metal-Cast Foundry, Agra.

10. AQ measuruments at the Taj Mahal, Agra.

11. Dr. M. Graber and the Air Monitoring Van at Taj Mahal, Agra.

12. Mr. K.S. Gussain and HiVol sampler at Taj Mahal, Agra.

APPENDIX 12.10



APPENDIX 12.11

26 March, 1987

Outline of the Agra Background Air Pollution Study (Phase I) - Holi (March, 1987)

1. Introduction

1. Problem of emissions from the Agra iron foundries.
2. Wide concern about adverse AP effects on the Taj.
3. Only little AQ data available.
4. Only little stack sampling.
5. PCRI hired by Agra Foudry Association and PPDC.
6. Background measurements during Holi feast, when foundries not working.
7. Object of project: AP impact of foundries on Taj, Agra Fort, Sikandra.
8. Use of Air Monitoring Van.
9. 2nd Phase: Monitoring when foundries operate
10. 3rd Phase: Develop AP control devices for Agra foundries.

2. Description of iron foundry industry in Agra

1. Typical foundry, scheme.
2. Number of foundries, distribution.
3. Raw materials: Ratio of, types, quantities.
4. Coke: Quantity, S %, Ash %, etc.
5. Foundries in industrial areas vs. foundries in residential area.

3. Type of air pollutants in the Agra area

1. Dust: Foundries
   CO: Foundries
   SO_2: Coke burning by foundries
   Possibly: Oil refinery in Mathura.
2. Dust emissions from iron foundries: Large
   SO_2 emissions from iron foundries: ? (dependent on S % in coke)
   CO emissions from iron foundries: Large, however, they do not affect stone monuments

4. Detailed description of Air Monitoring Van

1. List of instruments
2. Callibration procedures
3. Data logging and reporting capabilities
4. AC system and generator
5. Give pictures, diagrams and schemes

5. Ambient AQ sampling plan at Agra

1. Dates, sites and parameters monitored
2. Give map
3. Give description of each site (sources of pollution, residential or industrial, traffic, national monument, etc.)

6. Results and data analysis

1. Summary of results (give raw data in appendices)
2. Throw away wrong data (i.e., SO_2 for first hour)
3. Correct wrong data (SPM from Air Monitoring Van ?)

7. Discussion of results

1. Compare results with air quality standards in India and elsewhere (Stern. Vol.5, Newill): SPM, SO_2, CO, NOX (NO_2), O_3
2. Expected seasonal trends of these pollutants (especially in winter)
3. Meteorology: Wind direction, distribution - Taj, Fort Agra and Sikandra vs. Iron foundries, Mathura refinery

8. Conclusions

1. Conclusions derived from analysis of the monitored data: Is there, or is there not, a problem? If there is, what kind? Take into account Taj is a sensitive area with a high natural dust background (dust storms); Conclusions regarding: SPM, CO, SO_2
2. Conclusions regarding Sulphur and Ash in the Coke used by iron foundries, coke grade used by them
3. Conclusions regarding diesel generators
4. Conclusions derived from the analysis of the emission inventory completed by PPDC
5. Conclusions regarding seasonal variations of dispersion conditions in the Agra area (especially in winter)
6. Conclusions regarding summer O_3 concentrations
7. Conclusions regarding the dominant wind directions (iron foundries and Mathura refinery vs. Sikandra, Taj and Agra Fort)

9. Recommendations

1. Establish reliable values for coke quality used by Agra iron foundries (S %, Ash %). Perhaps recommend to upgrade coke quality?

2. Carry out AQ monitoring in Agra when iron foundries operate

3. Study the following means to reduce SPM and soot concentrations in Agra:

- Installation of control devices on the iron cupolas
- Locate all the Agra iron foundries in industrial areas

10. List of references

1. Stern, 1976: Air Pollution
2. Report of Control Board (CBPCWP): 1981
3. Other

11. Annexures

1. Raw data
2. Indian Air Quality Standards (official version)
3. Indian Emission Standards (official version)
4. Report on analysis of the coke used by the Agra iron foundries
5. Blank questionnaire issued by PPDC for survey of the Agra iron foundries
6. Properties of Indian coke and coal (based on a reliable source, e.g., the Coal Research Institute)

APPENDIX 12.12

AMBIENT AIR QUALITY STANDARDS

The following air quality standards were adopted by the Central Board for the Prevention and Control of Water Pollution in the 47th Meeting on November 11, 1982 in exercise of its jurisdiction under Section 16(2)(h) of the Air (Prevention and Control of Pollution) Act, 1981. These will be applicable for the period up to December 1985, over the entire country.

On the basis of land use and other factors, the various areas shall be classified into three categories by concerned State Pollution Control Board:

(A) Industries and mixed-use areas;
(B) Residential and rural areas;
(C) Sensitive areas.

Category A, will become self-evident on the intensity of industrial activity in an area and is bound to have somewhat inferior quality of air compared to other categories; Category C, will cover hill stations, tourist resorts, sanctuaries, national parks, national monuments, health resorts, and other such area where the nation would wish to conserve its clean environment even if that implies some curbs on economic activity. All areas not specificaly declared to belong to category A or C shall automatically fall into class B.

When monitored uniformly over the 12 months of a year witha frequency of not less than once a week, with a sampling time of eight hours for any sample, and analysed according to procedures specified by the Control Board, the concentrations for the following pollutants shall be, 95% of the time, within the limits prescribed below:

Area	Category	Concentration Microgramms per meter cube			
		SPM	SO2	CO	NOX
A.	Industrial and mixed-use	500	120	5000	120
B.	Residential and Rural	200	80	2000	80
C.	Sensitive	100	30	1000	30

Whenever and wherever three consecutive measurements spaced by at least one-week apart, or any three out of 10 consecutive measurements spaced by at least one-week apart are found to exceed limits specified above for the respective category, it would be considered adequate reason to institute regular weekly/ continuous monitoring and further investigations.

COMPREHENSIVE INDUSTRY DOCUMENT SERIES:
COINDS/17/1983-84

EMISSION REGULATIONS

(JULY 1984)

PART ONE

CENTRAL BOARD FOR THE PREVENTION AND CONTROL OF WATER POLLUTION
5TH & 6TH FLOOR, SKYLARK, 60, NEHRU PLACE,
NEW DELHI - 110019

THERMAL POWER

For the present, control equipment will be required in the thermal power stations to limit the particulate matter emission. For keeping the sulphur dioxide level in the ambient within the air quality standards, the method required shall be by a minimum stack height.

Basis

1. Seperate limits have been laid down for each of the following categories of boilers:

Description	Category
Less than 200 MW	(a)
200 MW and above	(b)

It is considered that category (a) will comprise mainly captive power of industries and existing thermal power plants (Utilities) operated by State Electricity Boards. Category (b) will comprise large thermal power stations operated by Central Agencies.

2. The limit would also vary depending upon the ash content of coal used. Emission factors for different types of boilers are furnished in Table 2.1.

Table 2.1: Emission Factors for Large Industrial Boilers (EPA: AP-42)

Type	Particulates kg/t of coal burned	Sulphur dioxide kg/t of coal burned
Pulverized coal	8.0(A)	19(S)
Wet bottom	5.5(A)	19(S)
Dry bottom	8.5(A)	19(S)
Cyclone	1.0(A)	19(S)
Spreader stocker	6.5(A)	19(S)

A = Percent Ash content of coal
S = Percent Sulphur content of coal

Sampling conducted at a recently commissioned 200 MW Thermal Power Station showed that 99.78% removal of particulate matter can be achieved with ESPs of latest indigenous design. The details are provided in Table 2.2.

Table 2.2: Electrostatic Precipitator Efficiency

Type	A	B	C
Inlet concentration of dust gm/Nm3	15.51	20.95	21.29
Outlet concentration of dust gm/Nm3	30.6	46.7	44.6
Efficiency	99.75	99.70	99.79

Source: Bharat Heavy ElectricalsLimited (BHEL)

In developing the standards it is considered that category (b) plants must install ESPs to achieve 99.78% removal as demonstrated at the above plant. A standard of 150 mg/Nm3 is proposed in these cases.

3.(a) In addition to the size of the boilers, qualified above, additional consideration should be given to its age and its location. The age is important from the point of view of the cost-benefit aspect and the location from its environmental impact.

3.(b) BHEL came out with their improved ESP design in 1979. Therefore, all plants commissioned after 31st December, 1979 are being classified as new plants. Even if the boiler has been installed prior to 1979, the plant will be classified as new, in this standard, if the ESP has been installed after December, 1979. New plants should meet an emission level of 350 mg/Nm3 (equivalent to about 99.4% collection efficiency). This is more relaxed than the standard for boilers greater than 200 MW because the emission load from the smaller boilers will be less. Further, for older plants, a standard of 600 mg/Nm3 is proposed because these plants may have constraints on funds. Finally, in areas where the environmental quality has to be protected, a standard of 150 mg/Nm3 is being adopted.

4. The standards adopted for the Thermal Power Plants are:

Boiler size	Old	New (after 1979)	Protected area
Less than 200 MW	600 mg/Nm3	350 mg/Nm3	150 mg/Nm3
200 MW and above	-	150 mg/Nm3	150 mg/Nm3

Stack Height Requirement for Sulphur-dioxide Control

To maintain a healthy ambient air quality the stack height for boilers should be as follows:

Boiler size	Stack height
200 MW and More to Less than 500 MW	220 Metres
500 MW and More	275 Metres
Less than 200 MW	$H = 14 (Q)^{0.3}$

Q = Sulphur dioxide emission in kg/hr

H = Stack height in metres

Flue Gas Desulphurization

No standard for sulphur dioxide emission is being prescribed, the control being effected through the height of the stack.

For plants having boilers of 500 MW and more, necessary space has to be provided for installing flue gas desulphurization device, should there be a requirement in the future.

GUIDELINES FOR MINIMUM STACK HEIGHT

1.

Plant Type	Stack Height
For all plants except Thermal Power Plant	30 m

2. For plants where the sulphur dioxide emission is estimated as Q (kg/hr) the stack height, H in metres, is given by

$$H = 14\ (Q)^{0.3}\ .$$

3. For plants where the particulate matter emission is estimated as Q (tonnes/hr) the stack height, H in metres, is given by

$$H = 74\ (Q)^{0.27}\ .$$

4. If using the formula given in 2 or 3 above, the stack height arrived at is more than 30 m, than this higher stack height should be used.

   In no case should the height of the stack be less than 30 m.

APPENDIX 12.13

Some Literature References on Environmental Impact Assessment

1. Barbaro r. & F.L. Cross, 1973: Primer on Environmental Impact Statements, Technomic Publ. Inc., Conn., USA, 140p, ISBN 0-87762-112-8.

2. Canter L.W. & L.G. Hill, 1979: Handbook of Variables for Environmental Impact Assessment, Ann Arbor Science Publ., Mich., USA, 230p, ISBN 0-250-4032108.

3. Cheremisinoff P/N. & A.C. Morresi, 1977: Environmental Assessment and Impact Statement Handbook, Ann Arbor Science Publ., Mich., USA, 438p, ISBN 0-250-40158-4.

4. Erickson P.A., 1979: Environmental Impact Assessment - Principles and Applications, Academic Press, NY, ISBN 0-12-241550-7.

5. Golden J., R.P. Ouellette, Sh. Saari, P.N. Cheremisinoff, 1979: Environmental Impact Data Handbook, Ann Arbor Science Publ., Mich. USA, 864p, ISBN 0-250-40212-2.

6. Munn R.E. (Editor), 1975: Environmental Impact Assessment: Principles and Procedures, SCOPE Report #5, UNEP, Env. CANADA and UNESCO, Toronto, Canada.

7. UNEP, 1980: Guidelines for Assessing Industrial Environmental Impact and Environmental Criteria for the Siting of Industry, United Nations Environmental Programme, Industry and Environmental Guidelines Series, Vol. 1, 105p, ISBN 92-807-1015-X.

APPENDIX 12.14

To: Shri A.K. Gupta
Manager, PCRI

From: Dr. M. Graber
UNIDO Expert

Date: 25 March, 1987

Sub: Review of PCRI Report on Air and Noise Pollution in the Central Plant Stores, HEEP, BHEL at Hardwar

1. Workers in the Central Plant Stores of the Heavy Electrical Equipment Plant (HEEP), BHEL at Hardwar were complaining about dust, odors and noise nuisances as well as high humidity levels inside their workplace. PCRI was asked to monitor the levels of these parameters and provide, if necessary, solutions to these problems.

2. PCRI staff carried out a detailed investigation of the conditions regarding dust, humidity and noise which exist inside and outside of the storage area and submited a full report on their finding. The report includes the results of the monitoring, analysis of the results and recommendations.

3. I reviewed the report together with Eng. Ambrish Goel and Eng. M.K. Ghosh, and following are my comments.

4. I fully agree with the recommendations of the report. The monitoring data indicates reasonable dust and humidity levels. There might be though, a humidity problem in the rainy season. In every event, as pointed out in the report, operating the ventilation system should overcome all the problems related to dust, odors and humidity.

5. Nevertheless, attempts should be made, as suggested in the recommendations, to improve the comfort of the workers inside the Central Plant Stores, such as:
- Provide adequate artificial light
- Remove workstations as far as possible from induction blowers, to minimize exposure to noise and draught
- Alternatively, replace the induction blowers of the ventilation system with suction fans. This should improve significantly the comfort of the workers by reducing the noise levels and the draught inside the store.

6. The subject of comfort of the workers inside the store, especilly the humidity problems listed in the recommendations of the report, should be discussed in detail in the report itself.

7. I would also suggest the following technical changes and additions to the report:

a. Insert numbers to pages, tables and figures.
b. Add a simplified diagram according to scale describing the outlay of the store, the location of the blowers, the exhausts, the workstations and the monitoring sites.
c. Add a list of references.
d. Prepare a title page that includes the name of the project, date of the report, serial number of the report, names and titles of investigators, the name of the institution (PCRI),as well as who ordered the project and to whom it was submitted.
e. Add a paragraph which describes in detail the instrumentation utilized for obtaining the air quality and meteorological data, as well as the noise levels presented in the report.

Sincerely yours

Michael Graber
(M. GRABER)

CC: Prof. S.P. Mahajan
Eng. M.K.Ghosh
Eng. A. Goel

APPENDIX 12.15

Some Important ASTM Standards Relating to Atmospheric Sampling and Analysis

See: Annual Book Of ASTM Standards, Section 11: Water and Environmental Technology, Volume 11.03: Atmospheric Analysis; OccupationalHealth and Safety, Philadelphia, PA, USA.

1. ASTM D-1356-73a: Standard Definitions of Terms Relating to Atmospheric Sampling and Analysis.

2. ASTM D-1357-82: Standard Practice for Planning the Sampling of the Ambient Atmosphere.

3. ASTM D-1605-60: Standard Recommended Practices for Sampling Atmospheres for Analysis of Gases and Vapors.

4. ASTM D-2820-72(1978): Test Method for C1 Through C5 Hydrocarbons in the Atmosphere by Gas Chromatography.

5. ASTM D-3211-79: Standard Test Method for Relative Density of Black Smoke (Ringelmann Method).

6. ASTM D-3249-79: Standard Recommended Practice for General Ambient Air Analyser Procedures.

7. ASTM D-3609-79: Standard Practice for Calibration Techniques Using Permeation Tubes.

8. ASTM D-3614-81: Standard Practice for Evaluating Laboratories Engaged in Sampling and Analysis of Atmospheres and Emissions.

9. ASTM D-3687-84: Standard Practice for Analysis of Organic Compound Vapors Collected by the Activated Charcoal Tube Adsorption Method.

10. ASTM D-4096-82: Standard Practice for Application of the HI-VOL (High - Volume) Sampler Method For Collection and Mass Determination of Airborne Particulate Matter.

11. ASTM D-4185-83: Standard Test Method for Metals in Workplace Atmosphere by Atomic Absorption Spectrophotometry.

12. ASTM D-4490-85: Standard Practice for Measuring the Concentration of Toxic Gases of Vapors using Detector Tubes.